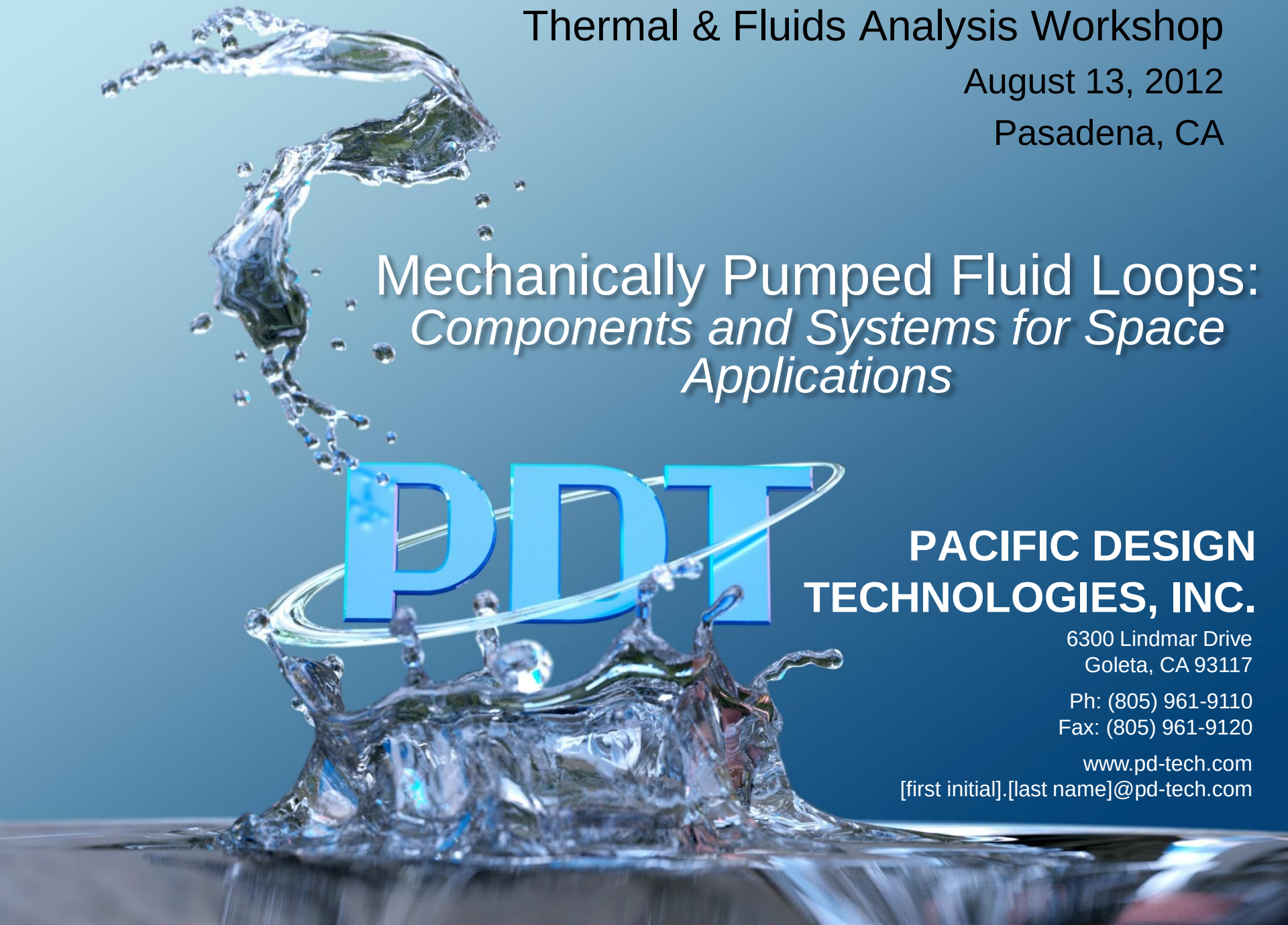
Thermal & Fluids Analysis Workshop

August 13, 2012

Pasadena, CA

Mechanically Pumped Fluid Loops:
Components and Systems for Space Applications



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Mechanically Pumped Fluid Loops

- Typical Mechanically Pumped Fluid Loop
- System Considerations
- Past and Present Systems
- Testing Protocol
- Performance Measurement
- Future Trends

Typical Mechanically-Pumped Fluid Loop

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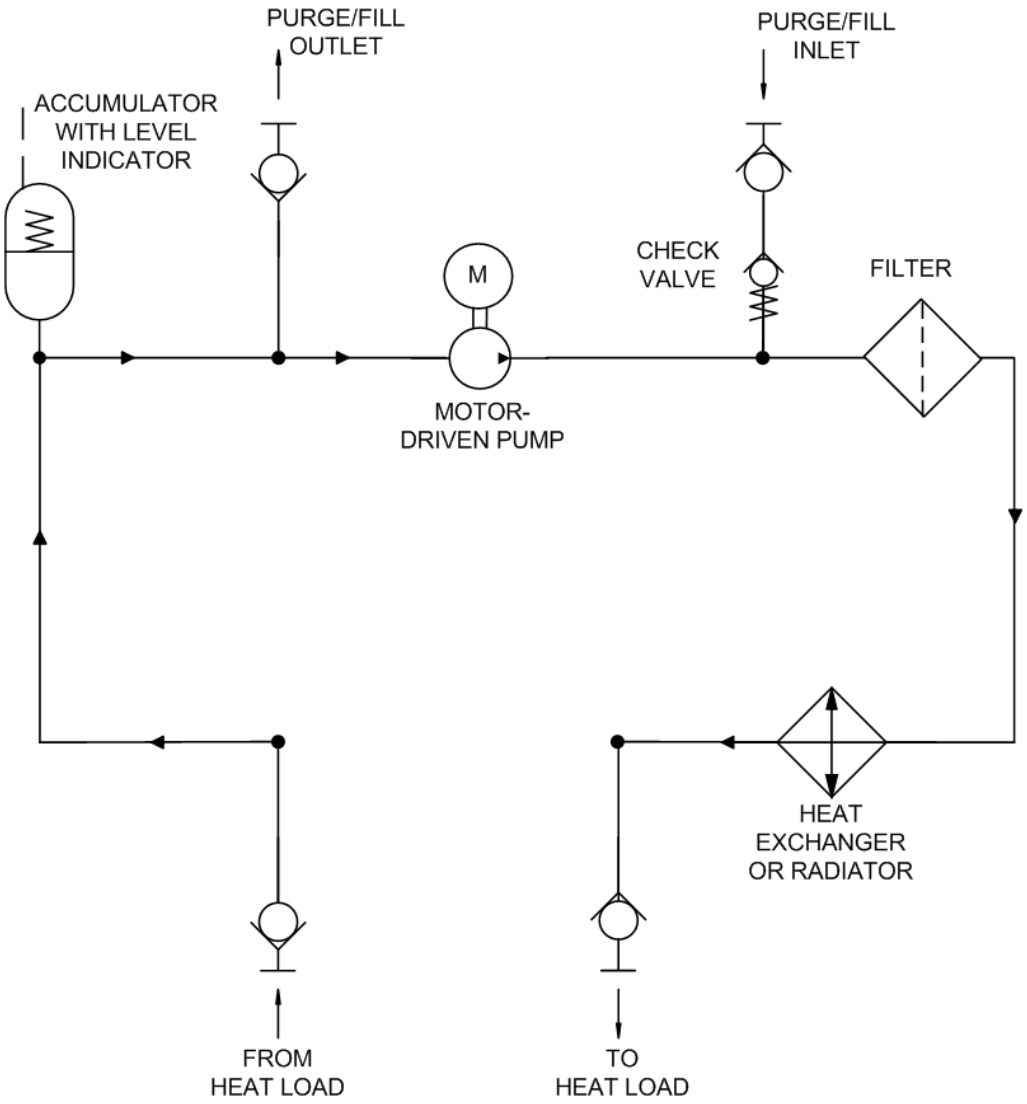

Liquid Cooling Systems for Airborne Applications

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BAMS LSCU

Firescout LCS

ISR Aircraft LCS

Liquid Cooling Systems for Space Applications

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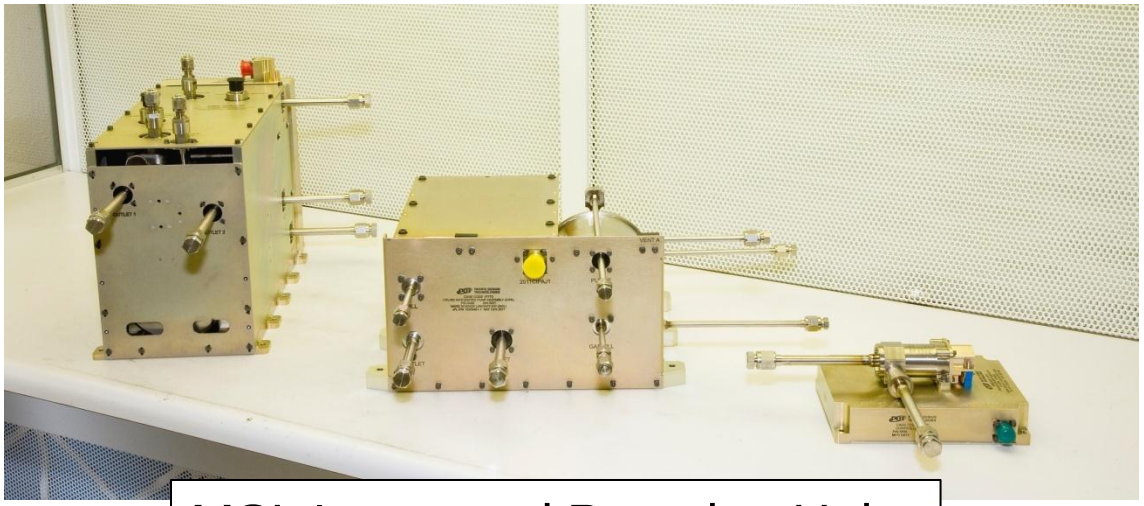
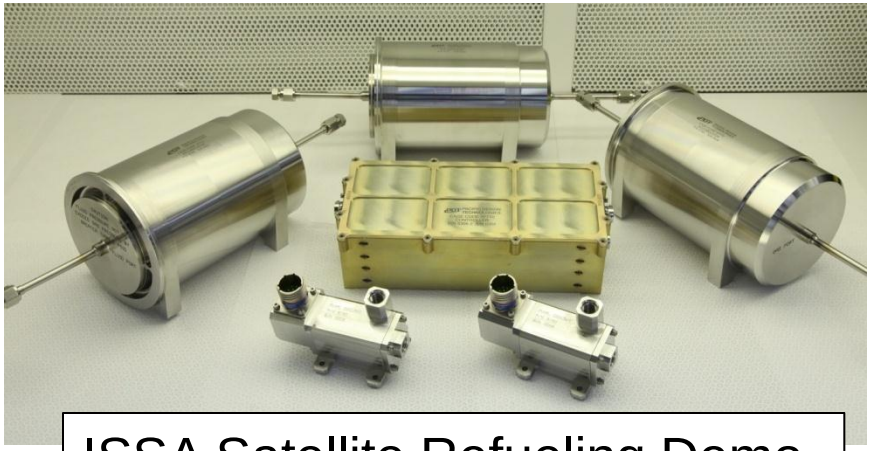


MSL Integrated Pumping Units



ISSA Satellite Refueling Demo.

AMS-2 Pump and Controller

System Considerations

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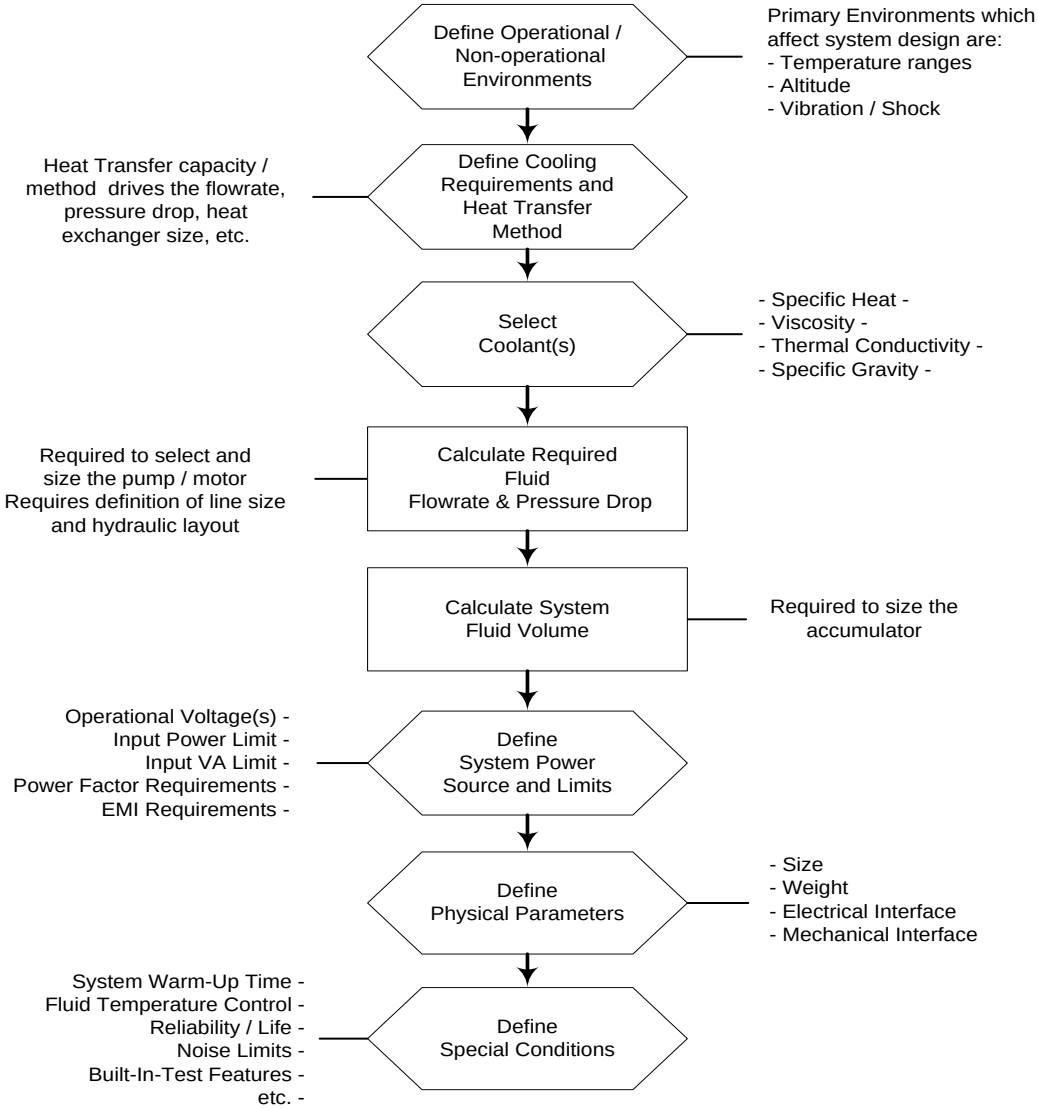

Unique Requirements for Space Applications

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Challenge	Feature(s)	Benefit
Long-duration missions	• All-welded construction (no elastomeric seals) • Flooded pump motors (no shaft seals)	High reliability
Strict cleanliness and material compatibility requirements	• CRES wetted materials • Canned (sealed) motors • Carbon bearings	Reduced potential for material interactions
Wide temperature range	• Limited material list • Appropriate fits/clearances	Reduces thermal expansion issues
Tight power budget	• Small motors • Low flow rates • Minimize system pressure drop • Passive thermal control valves	Reduced power consumption

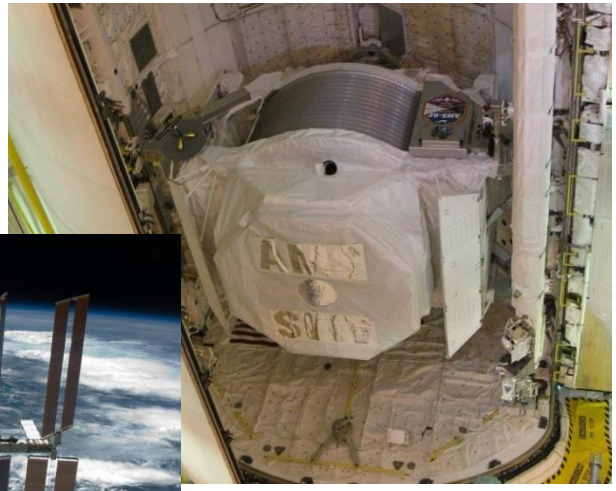
Past and Present Systems

Integrated Pump Assemblies

- Mars Pathfinder (cruise stage)
- Mars Exploration Rover (cruise stage)
- Mars Science Laboratory (cruise stage and rover)

Pumps and Accumulators

- AMS-2 Tracker
- Satellite Refueling Demonstrator



Thermal Control Valves

- Part of Mars IPA's
- "Smart" Loop Heat Pipes (ground demo projects)

Testing Protocol

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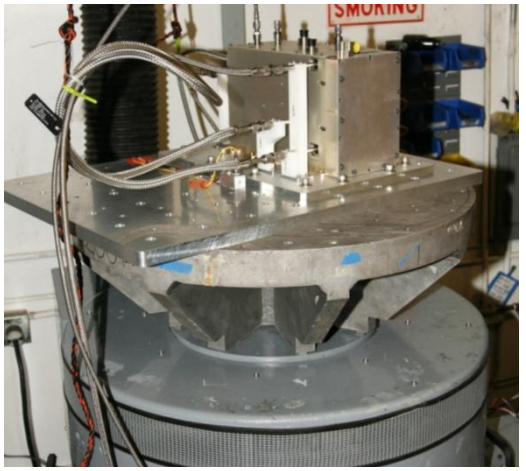
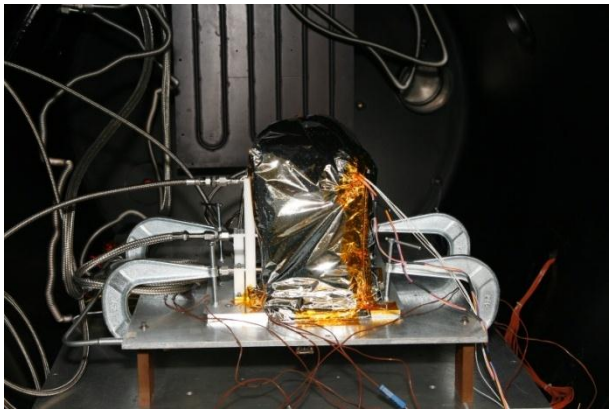
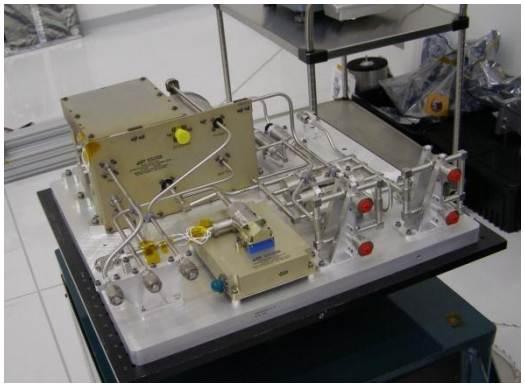
Typical Test Sequence

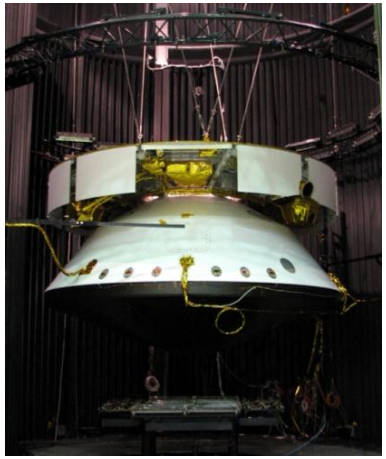
- Component performance testing, lab ambient environment
- Pre- and Post-Welding performance, lab ambient environment
- Proto-flight Vibration and Shock
- Thermal Vacuum Cycling
- Performance Mapping
- Integration testing (by customer)
- Vehicle testing (by customer





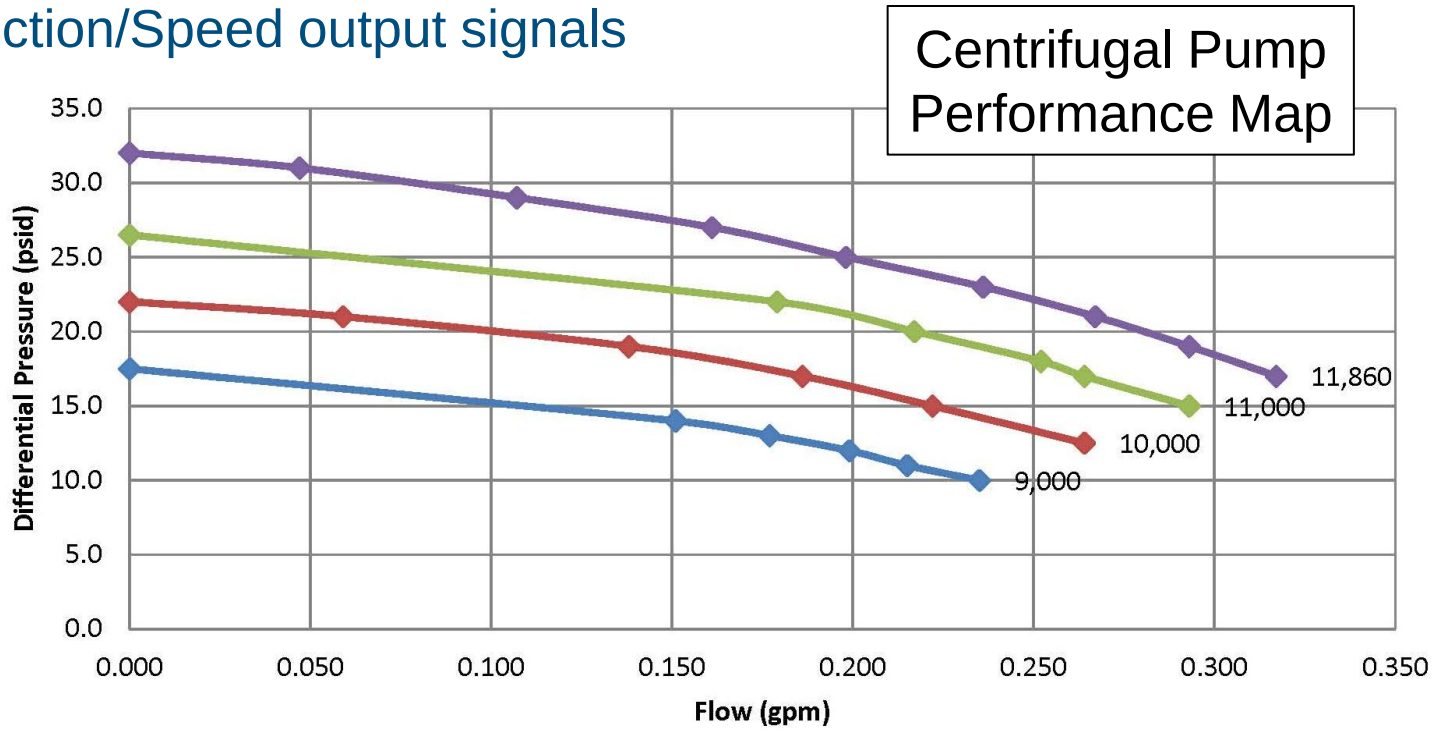
MSL Hardware Testing





Pump Performance

- Flow, pressure rise and power consumption
- Speed control, start-up and high/low temperature performance
- Current/Power Limiting circuitry
- Fault detection/Speed output signals



Performance Measurement

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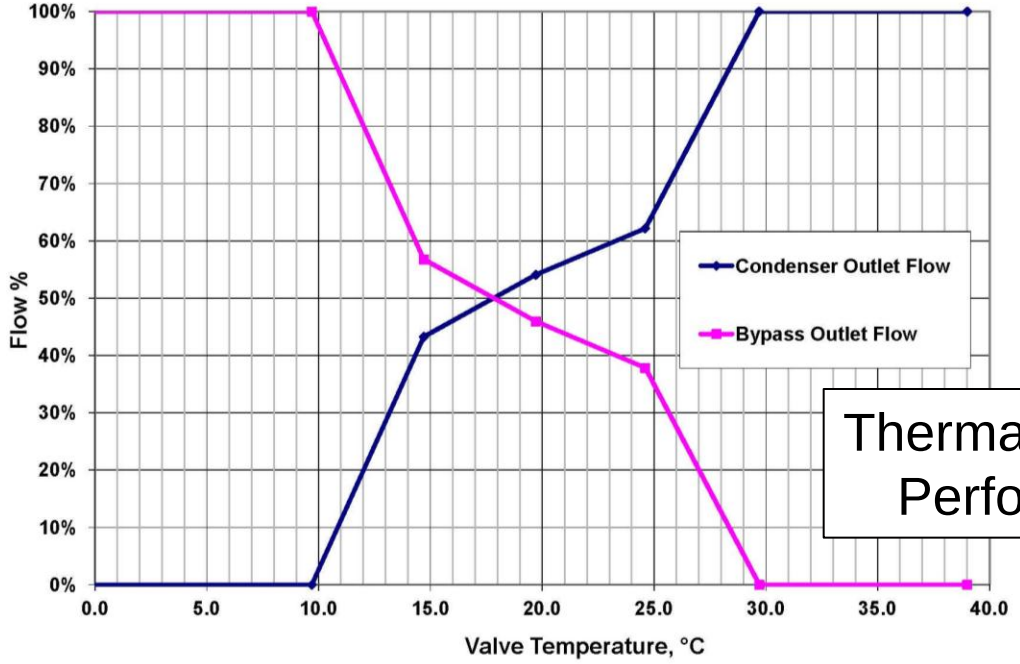
Accumulator Performance

- Displaceable volume
- Pressure vs. volume performance

Thermal Control Valve Performance

- Flow rate vs. temperature
- Flow and pressure drop performance

Accumulator Performance Test



Thermal Control Valve Performance Map

Future Trends

Performance Enhancements

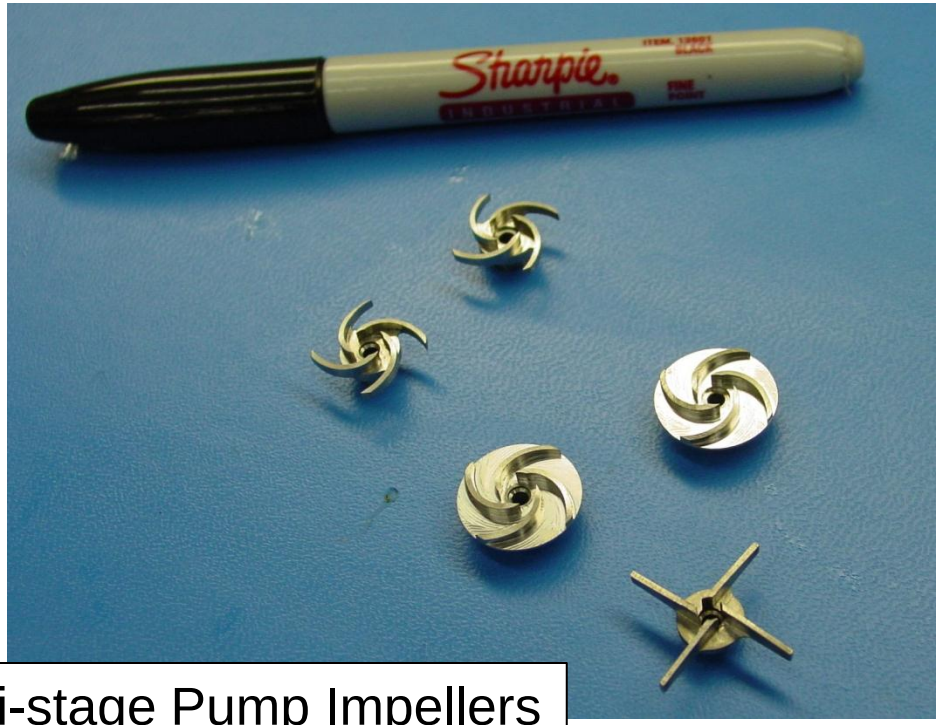
- Higher pump efficiency through impeller changes, and multi-stage pumps
- Sensorless motor controls to eliminate position sensors
- High temperature electronics
- Controller miniaturization

Alternate Fluids

- Reduce use of ozone-depleting chemicals

Thermal Control Valves

- New system architectures



Multi-stage Pump Impellers

Summary

- Pumped-loop systems provide relatively high capacity heat transfer performance in a small package
- High reliability systems have been proven through multiple long-duration missions
- Electric power consumption can be minimized through proper system sizing
- Materials and processes well established
- Established supply base minimizes program risk
- Advances in electronics offer future improvements in size/weight/power
- Innovative architectures under development